MINCAI

ANTITRUST DIVISION
ATTN: LEGAL RESEARCH &
DATA RETRIEVAL UNIT
DEPARTMENT OF JUSTICE
WASHINGTON 25, D. C.

RECEIVED
JAN 19 1962

253212

BRL

REPORT NO. 1115
MARCH 1961

A THIRD SURVEY OF DOMESTIC ELECTRONIC DIGITAL COMPUTING SYSTEMS

Martin H. Weik

ASTIA
RECEIVED
OCT 20 1961
TIPDR

This report supersedes BRL Report No. 1010

Department of the Army Project No. 5B03-06-002
Ordnance Management Structure Code No. 5010.11.812

BALLISTIC RESEARCH LABORATORIES

ABERDEEN PROVING GROUND, MARYLAND

LINCOLN TX 0

Lincoln Test-Experimental Computer Model 0

MANUFACTURER

Lincoln Laboratory
Massachusetts Institute of Technology

Photo by Lincoln Laboratory, Massachusetts Institute of Technology

APPLICATIONS

Manufacturer

An experimental digital computer used to test advance design techniques, including very large core storage and transistor circuitry.

The research reported in this computing system description was sponsored jointly by the Army, Navy and Air Force under contract with the Massachusetts Institute of Technology.

PROGRAMMING AND NUMERICAL SYSTEM

Internal number system	Binary
Binary digits/word	18
Binary digits/instruction	18
Instructions/word	1
Instructions decoded	25
Arithmetic system	Ring-adder
Instruction type	One address
Number range	Not appropriate

Three instructions are addressable and 1 is micro-programmable.

ARITHMETIC UNIT

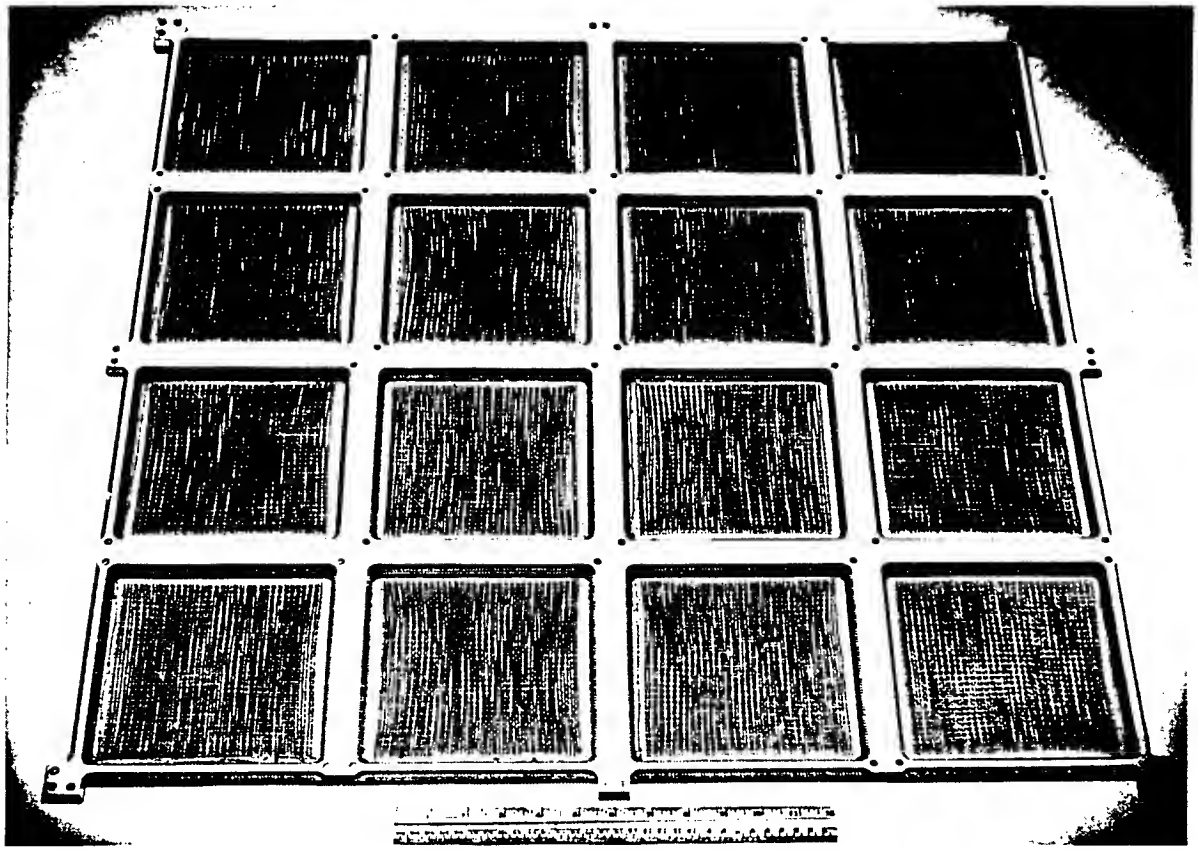
	Incl Stor Access Microsec	Exclud Stor Access Microsec
Add time	6	1
Mult time	1,000	1,000
Div time	1,000	1,000
Construction		1,000 transistors
Arithmetic mode		Parallel
Timing		Synchronous
Operation		Concurrent

Computer performs 83,000 additions per second. Mulitply and divide is programmed.

STORAGE

Media	Words	Digits	Microsec
Magnetic Core	65,536	18/word	3
Flip-flop	1	18/word	0.5
Toggle Switch	16	18/word	3

A parity bit is additional. Read-rewrite time is 6 microseconds.



LINCOLN TX 0 and TX 2 Memory Plane Photo by Lincoln Laboratory, Massachusetts Institute of Technology

INPUT

Media	Speed
Photo Reader	250 lines/sec
Flexowriter	Manual
Toggle Switch	Manual

OUTPUT

Media	Speed
Flexowriter	10 char/sec
Display (CRT)	16 microsec/spot

CIRCUIT ELEMENTS OF ENTIRE SYSTEM

Tubes	440
Tube types	3
Crystal diodes	350
Magnetic cores	1,245,773
Transistors	3,500
Separate cabinets	5

Three major tube types, a small number of others. Most tubes are used in the large memory. The transistors are the Philco L-5122 Surface Barrier Transistor.

CHECKING FEATURES

Parity check on memory systems. Marginal checking is built in.

POWER, SPACE, WEIGHT, AND SITE PREPARATION

Power, computer	10 Kw
Volume, computer	1,000 cu ft
Area, computer	200 sq ft
Capacity, air conditioner	40 Tons
Weight, computer	4,000 lbs

Above figures are approximate. Air conditioner is necessary for memory only.

PRODUCTION RECORD

Number produced	1
Number in operation	1

ADDITIONAL FEATURES AND REMARKS

One picture shows close-up view of magnetic core memory plane and other picture shows random-access core memory, frame of memory-core selection-switch drivers, computer arithmetic element and control element, and computer operating console.

INSTALLATIONS

Lincoln Laboratory
Massachusetts Institute of Technology
Lexington 73, Massachusetts

LINCOLN TX 2

Lincoln Test Experimental Computer 2

MANUFACTURER

Lincoln Laboratory
Massachusetts Institute of Technology

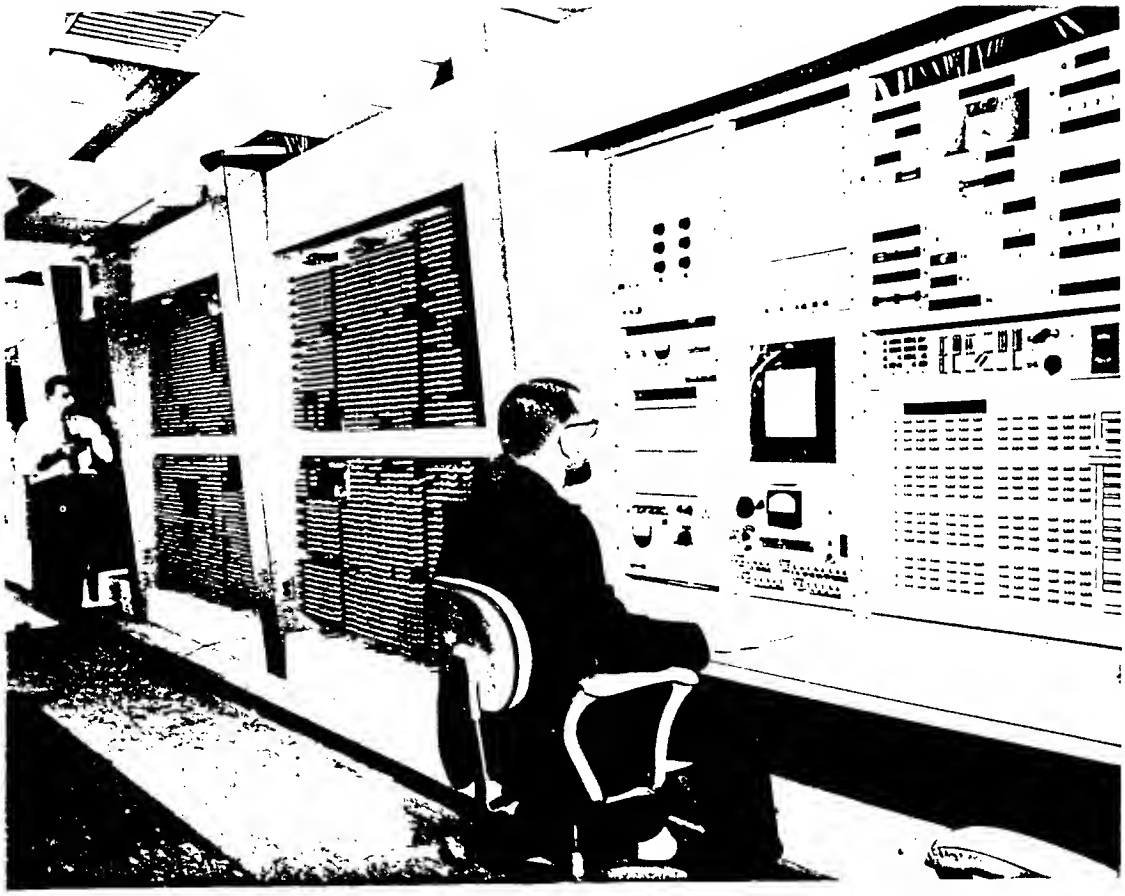


Photo by Lincoln Laboratory, MIT

APPLICATIONS

Computing system is used for scientific research and for the simulation, analysis, and control of real time systems.

PROGRAMMING AND NUMERICAL SYSTEM

Internal number system	Binary
Binary digits/word	36 + 1 + 1
Binary digits/instruction	36 + 1 + 1
Instructions per word	1
Instructions decoded	64
Arithmetic system	Fixed point (Ones complement binary)
Instruction type	Indexable; Indirect addressing on all instructions
Number range	$-(1 - 2^{-35})$ to $(1 - 2^{-35})$

Instruction word format

1	1	5	6	6	1	17
meta bit	hold bit	configuration reg. no.	op code	Index register	indirect address bit	base address

All fixed programs are in toggle switch or plugboard storage.

Automatic coding includes standard compiler, which provides full symbolic coding facilities.

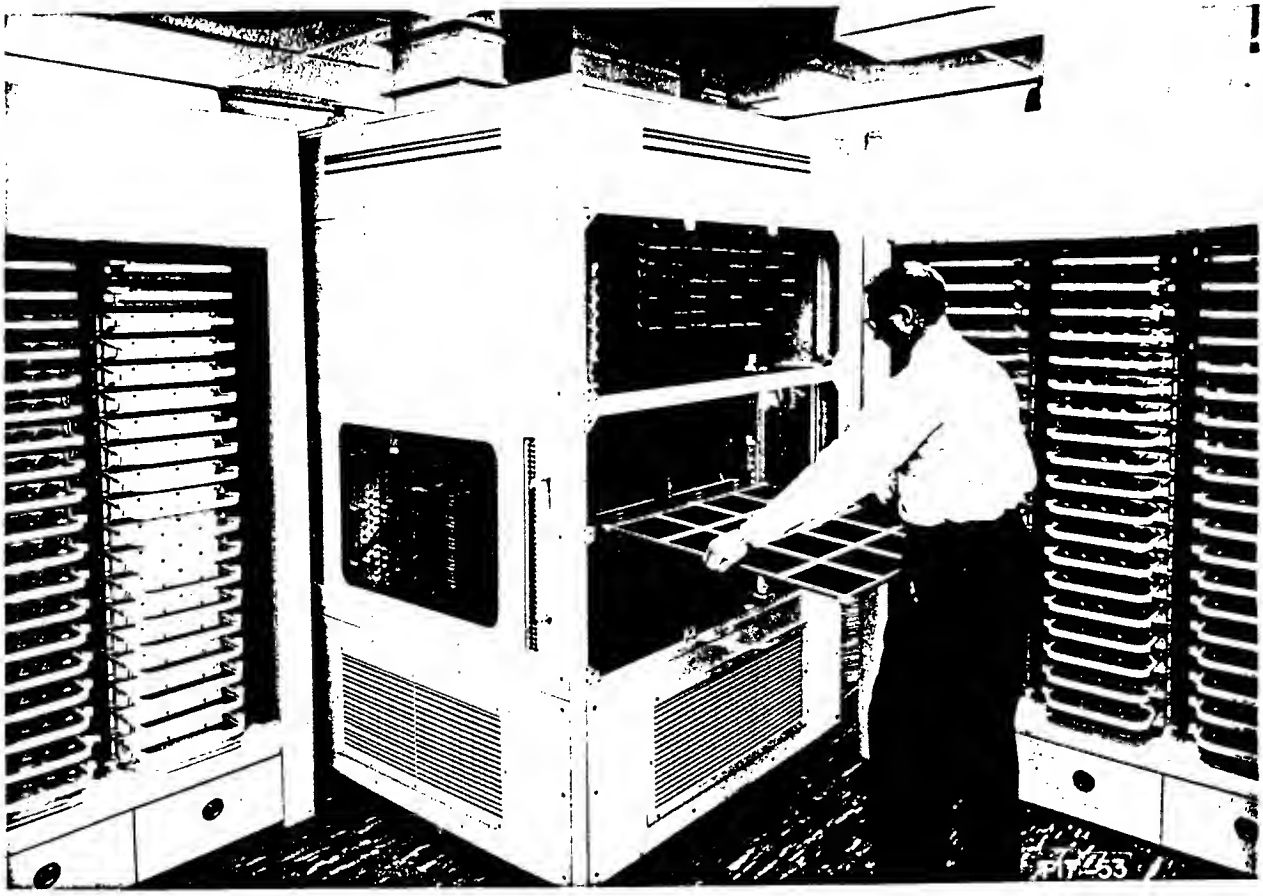
All four arithmetic registers and the exchange register are addressable as part of memory. There are sixty-four 18-bit parity-checked index registers.

Indirect addressing can be repeated indefinitely.

33 program (instruction) counters are provided, only one of which is used at a time.

Each in-out unit is associated with a program counter. Choice of program counter is determined by in-out unit, by program, and by relative priority of program counters.

Any instruction can specify a configuration of the computer during the execution of the instruction. A 36 bit operand word can be divided into one 36, one 27 and one 9, two 18, or four 9 bit subwords formed from the 9 bit quarters. The 9 bit quarters can be permuted among themselves. Any or all of the subwords can be used simultaneously. For example, two 18 bit multiplications are done by one multiply instruction in less time than one 36 bit multiplication.



Memory Stall

Photo by Lincoln Laboratory, MIT

One bit of each computer memory word is used for parity checking. The other is used as a tag bit for program debugging.

ARITHMETIC UNIT

	Incl. Stor. Access Microsec	Exclud. Stor. Access Microsec
Add	4.8	1.4
Mult	9.6 - 19.2	5 - 17 (9 bit-36 bit)
Div	19.6 - 80.0	17.2 - 75 (9 bit-36 bit)

Construction (Arithmetic unit only)	
Transistors	8,800
Arithmetic mode	Parallel
Timing	Synchronous
Operation	Concurrent

The following table lists the number of thousands of arithmetic operations of a given type which can be executed per sec.

Word Length in Bits	36	27	18	9
Arithmetic	+ 200	200	400	800
Operation	x 50	67	17	400
	÷ 13	17	48	200

STORAGE

Media	No. of Words	Read-Write Time	No. of Digits/Word	Microsec
Magnetic Core S Memory	65,536	6.4	36 + 1 + 1	3.4
Magnetic Core T Memory	4,096	4.4	36 + 1 + 1	2.2
Toggle switch, plugboard, etc	80	4.8	36 + 1	2.6
Magnetic Core Index Memory	64	3.4	18 + 1	0.6
Magnetic Film Config. Memory	32	0.8	9 + 1	0.3

Magnetic Tape	
No. of units that can be connected	512 Units
No. of lines /er linear inch	330 Lines/inch
Channels or tracks on the tape	10 Tracks/tape
Blank tape separating each record	0 Inches
Tape speed	30-1000 Inches/sec
Transfer rate	3,300-37,500 Chars/sec
Start time	250 Millisec
Stop time	10,000-250 Millisec
Physical properties of tape	
Width	3/4 Inches
Length of reel	7,200 Feet
Composition	Mylar type 189 3M

Tape reels are not changed.

Fixed address system (like drum). Variable read speed.
32 tape unit drives can be treated as 10^{10}-bits of internal storage.
14" NARTB reel.
Recording channels are paired. One pair is used for timing marks, another for block marks, and the remaining three for information. Three lines of information form the standard unit of information, a 9 bit character.

INPUT

Media	Speed
Paper Tape	3000 7 bit lines/sec peak speed
Speed is not constant. Accelerates slowly compared to line width.	
Keyboard	10 6 bit char/sec
Lincoln Writer input	
Analog-Digital Converter	40,000 11 bit samples/sec
Epsco Datrac converter	
Light pen/eye	Manual
Signals selected by operator	
Random No. Gen.	18,000 9 bit words/sec
Radioactive source	
Miscellaneous Input	80 KC
9 channel pulse input to computer from miscellaneous devices.	

OUTPUT

Media	Speed
Paper Tape	180 7 bit lines/sec
Soroban punch	
Xerox printer	20 lines/sec
	1300 char/sec
88 characters can be printed in 2 sizes. 6 bit vert. & 9 bit horiz. axes resolution.	
Typewriter	10 6 bit char/sec
Lincoln Writer output	
CRT point display & Camera	10 KC - 40 KC
10 bit resolution in both axes	
Miscellaneous output	Up to 500 cycles
9 channel switch for computer control of low rate devices	
Large board plotter	15 in/sec slew speed
PACE plotter	

Several input-output units can operate simultaneously so long as the time required by all the units operating does not saturate the central computer. Each unit has at most a single-line buffer; whenever a line of data needs to be transmitted to or from the central computer the unit causes the central computer to use its associated program counter. The machine can compute while in-out units are operating.

At peak rate, about 80,000 computer words/sec can be transferred into or out of the computer.

CIRCUIT ELEMENTS OF ENTIRE SYSTEM

Type	Quantity	Use
Tubes		
6888	69	Clock pulse amplifiers
5998	312	S memory
Z-2177	296	S memory
Misc. Types	88	
Diodes		
CTP592	3,000	Input-output circuitry
1N625	736	Input-output circuitry
Misc. Types	1,488	Input-output circuitry
Transistors		
L5122	26,042	
L5134	31,928	
2N501	320	
2N357	1,016	
Misc. Types	2,227	
Magnetic Cores		
	2,490,880	S memory
	155,648	T memory
	2,432	X memory

All the vacuum tubes are used in the 65,536 word memory and in the generation of the computer clock pulses.

Resistor coupled transistor logic in the central computer operates at a 5 megapulse per second rate.

Thin magnetic film memory contains 320 magnetic spots.

CHECKING FEATURES

Checking features include a single bit odd parity check on all memories, a voltage margin check on all bias voltages, and a manual switching system selects circuits to be checked. A built-in sync system facilitates locating machine errors. A library of test programs are used which check the operation of the computer and which attempt to induce errors.

POWER, SPACE, WEIGHT, AND SITE PREPARATION

Power, computer	20 Kw	25.6 KVA	0.8 pf
Power, air conditioner	17 Kw		
Area, computer		1,500 sq ft	
Area, air conditioner		350 sq ft	
Room size, computer		54 x 29	
Room size, air conditioner		17 x 20	
Capacity, air conditioner		25 Tons	

Cables run through overhead wireways. Air conditioning ducts also runoverhead. An 8 ft high false ceiling is hung to cover these. Otherwise building is standard. Most power supplies are solid state. Principally required for memories.

PRODUCTION RECORD

Number produced to date	1
Number in current operation	1
One-of-a-kind research computer	

PERSONNEL REQUIREMENTS

Problem originators are trained to use the computer. Paper-tape preparation facilities and utility programs available to all computer users.

Three engineering assistants and one technician are available to do routine maintenance and to make changes in the computer system.

RELIABILITY, OPERATING EXPERIENCE, AND TIME AVAILABILITY

As a research machine, TX-2 operating experience is good but though data is kept on machine failures, no reliability figures have been computed.

Basic circuits and components are similar to MIT's TX-0 machine.

ADDITIONAL FEATURES AND REMARKS

Outstanding features include an operating thin magnetic film memory; 65,536 word magnetic core memory. Fixed address magnetic tape system. Multiple-sequence operation of computer and simultaneous operation of input-output units permits considerable flexibility in use of in-out units. Maximum execution time for any one arithmetic instruction can be reduced to one memory cycle time by overlapping instructions and memories.

Unique system advantages include multiple-sequence operation, configuration control over operands, thin magnetic film memory used in control element of computer, and 64 index registers stored in random access magnetic core memory.

The Lincoln Writer input-output unit permits considerable flexibility in communicating with the computer.

FUTURE PLANS

Another 4096 word magnetic core memory will be installed in order to increase opportunities for overlapping operation of memories.

A magnetic tape unit will be installed which will be compatible with units used on many commercial computers.

Input-output units will be added as the needs develop.

A new control console will replace the present console.

INSTALLATIONS

Lincoln Laboratory
Massachusetts Institute of Technology
P. O. Box 73
Lexington 73, Mass.